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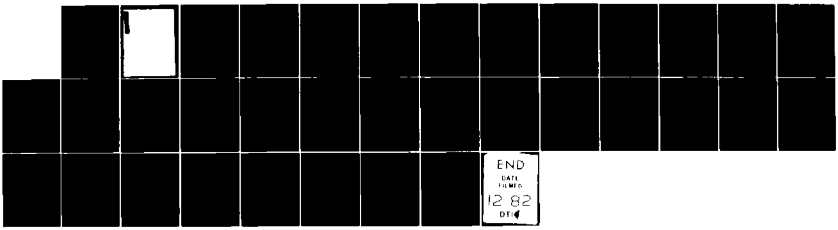

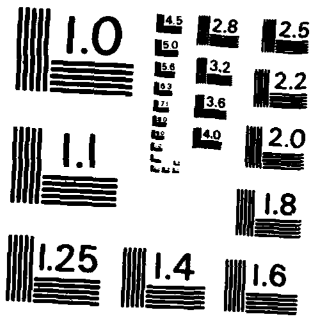
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CONCEPTS FOR ARMY USE OF ROBOTIC-ARTIFICIAL INTELLIGENCE IN THE 21ST CENTURY

by

Dennis V. Crumley

1 June 1982

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ABSTRACT

This report identifies potential military applications of robotic-artificial intelligence technology and considers near-, mid-, and far-term technological projections. Criteria for applications include their potential cost effectiveness, as already proven in civilian industry; the speed, accuracy and uniform quality of effort which robots can achieve; their ability to perform in hazardous environments; their role as soldier replacements or multipliers; and their ability to save lives on high risk missions.

The author concludes that there are a great many feasible applications, but for the Army to realize the great potentials of this field by the turn of the century, research and development in all robotic related sciences must be better funded and better coordinated. The author makes the following recommendations: Training and Doctrine Command should verify the potential applications as soon as possible, arrange them in order of tactical importance, and relay those requirements to materiel developers. Department of Defense/or Department of Army should take the top two or three of the most important applications and have them pursued independently by agencies which are unencumbered by normal research and development bureaucracies.

FOREWORD

This futures report is structured to be compatible with an overall approach of identifying materiel requirements within a concept-based environment. Although the functional areas of the Airland Battle 2000 concept are used as a means for considering robotic-artificial intelligence applications, consideration was not constrained only to that concept's environment. Other future force concepts, such as A Concept of a Future Force and The Year 2000 and the US Army were also assessed for potential applications for the state of the art over the next 20 to 25 years.

This report was prepared as a contribution to the field of national security research and study. As such, it does not reflect the official views of the US Army War College, the Department of the Army, or the Department of Defense.

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Dennis V. Crumley, LTC(P), USA, is an action officer assigned to Headquarters, Department of the Army, Office of the Deputy Chief of Staff for Operations, Training Directorate. He was commissioned in the Armor Branch of the US Army from East Tennessee State University in 1961. After a tour of duty in Germany and attendance at the Infantry Officer Advanced Course, he served in South Vietnam with the 11th Armored Cavalry Regiment. Following successive tours as a staff officer at Fort Knox, Kentucky, and Headquarters V Corps, US Army Europe, he served as Commander, 2nd Battalion 33rd Armor, 3rd Armored Division, from 1977 to 1980 and served as Special Assistant to the Commander, Training and Doctrine Command from 1980 to 1981. LTC Crumley earned a Master of Arts degree in Latin American History in 1972 at the University of Alabama. He is a 1972 graduate at the Armed Forces Staff College and a 1982 graduate of the US Army War College. LTC Crumley is a member of the Society of Mechanical Engineers and Robotics International.

CONCEPTS FOR ARMY USE OF ROBOTIC-ARTIFICIAL INTELLIGENCE IN THE 21ST CENTURY

Introduction.. Robotics-artificial intelligence is a term generally used when describing the combined use of robots and microcomputers. It is an exciting, ever-expanding and almost unlimited field of technological exploration. Industrial robots are among the "hottest" technologies in today's economy. The primary thrust of US domestic interests in robotics to date, however, seems to be in factory automation . . . driven by the view that robots, together with artificial intelligence, will help make US industry more productive and competitive. Current efforts to refine this technology are constrained in time and focus primarily on near-term applications.

As the field of robotics develops, wider applications can be expected. For instance, forecasts from the American Society of Manufacturing Engineers and the University of Michigan indicate that by 1985 20 percent of the labor force in the final assembly of cars will be replaced by automation, and "vision systems" incorporated in robots will provide enough feedback for them to select parts scrambled in a bin; and, by 1990, the development of other sensory techniques will enable robots to approximate human capabilities in assembly tasks.[1]

To capitalize on this fast growing technology, the US Army, as well as the other services, should be considering robotic-artificial intelligence applications which meet one or more of five criteria:

- Cost effectiveness of the application surpasses traditional way of doing the task.
- Speed, accuracy, uniform quality of effort can be enhanced.

- o Capable of performing soldier tasks in hazardous environments.
- o Can either replace soldiers or multiply their effectiveness.
- o Could save lives in high risk missions.

Having identified applications which meet these criteria, the Army must channel technological efforts toward those which support operational concepts. This approach, referred to by the Training and Doctrine Command (TRADOC) as the Concept Based Requirements System, assures that materiel requirements meet anticipated operational needs rather than, as has happened in the past, operational concepts or doctrine being developed around available materiel.[2]

In keeping with this System, this study considers potential robotic-artificial intelligence applications within the functional areas of the Airland Battle 2000 concept. These applications go beyond the current state of the art in remote control and automation. They are conceptual, yet feasible, by most measures of robotic technological progress.

A Robotic-artificial Intelligence Primer. Any appreciation of how robotics-artificial intelligence could contribute to battle in the 21st Century must begin with a basic understanding of robotics itself; what it is, what the focus has been, where the technology is headed, and, finally, some potential applications.

A "robot" is a machine which can be programmed to perform a variety of manipulative tasks. Artificial intelligence refers to the ability of machines to learn, apply knowledge, reason deductively, make decisions and communicate ideas. When robots are linked to microcomputers which provide these capabilities, they are often referred to as "smart robots." Invariably, when robotic applications are considered for use in the next century, artificial intelligence will be inherent to those systems. The term robotics refers to a field of interest concerned with the construction, maintenance, and behavior of robots. Finally, the three key points which describe robots are that they can be readily programmed, can perform a variety of tasks automatically, and, in some ways, can function similar to humans.

Most current robotic systems can be viewed as first generation efforts, characterized by limited programming capabilities. Successful use of such robots is highly constrained by their environments which must be structured in terms of space and work-piece orientation. Typical tasks for today's robots are parts transfer or welding and spray painting, or similar tasks which are hazardous to a human's health.

Second generation robots--which are often "smart" robots--have sophisticated programs, incorporate sensor systems, and can react to changes in routine. By installing microcomputers in robots, they become, in a sense, "trained" to the needs of those for whom they work. For instance, today there is in use at a number of industrial plants a driverless robot cart, known as a minicart, which can travel by itself and load or unload work materials automatically.[3] These carts have been "trained" to the point that they can call their own elevators; travel up, down, or between levels; and work their way across bridges from one building to another. Similar carts have also been installed in hospitals to carry medicine and other supplies to patient's rooms.

The third generation of "smart" robots could become even more natural and easy to use if present trends continue. These third generation systems, existing today for the most part only conceptually or in laboratories, will have greatly expanded sensory capabilities. Artificial intelligence will be common to their design. They are, or will be, semiautonomous and able to accommodate wide variations in their environments without reprogramming.

A number of trends characterize the future of robotics. First is their "humanization"--the trend toward embedding computers into machines to train them and thus make them convivial computerized systems. A second trend is to "smarten-up" the relationship between man and machine to make the machines easier to use, thus more compatible. A third trend is to create new classes of machines such as "mind amplifiers" and "knowledge-based" systems. Knowledge bases are a next step beyond data bases. They contain in their memory more than raw data. Typically, their contents are equivalent to the information and processes which, theoretically, experts use for manipulating information in solving problems, making decisions, and learning.[4]

One can see from this description that the minicarts of today are but rudimentary forerunners of what could be tomorrow. It is not too far from the time when vehicles can be programmed with "smarts" that include microradars capable of looking to the front, back, and sides, thus sensing the vehicle's movement and orientation toward objects. These vehicles will also be able to sense curves in a route, determine surface conditions (dry, wet, icy, etc.), and other traffic along the route. Still other sensors will be able to detect and measure the vehicle's condition (speed, turning ability, braking capability, etc.). Microcomputers will accept and process these sensed external and internal environmental signals, compute critical thresholds (nearness to collision, condition of highway, etc.) and, when a threshold is reached, will send signals to actuators or controllers (possibly small electrical or non-fossil fuel motors) embedded in the brakes, wheels, throttle or starter to vary the vehicle's movement.[5]

Recent developments in robotics have resulted from the combining of industrial engineering automation technology and the computer science, artificial intelligence field. Because of this union, most informed observers consider the future of robotics as virtually limitless. Eventually, robots will store and recall knowledge about their environment which will allow them to perform intelligently as well as show a measure of insight regarding the environment in which they operate. Higher order computer languages, computer-aided instruction, and sophisticated control systems will eventually make it possible to instruct robots using vocabulary syntax much like that one might use in everyday conversations. It is only a matter of time and expenditure of research and development funds before sensors and control systems are developed that can produce highly skilled behavior in robots.

Scientists in the field of robotics project that a flexible robot could easily be produced in this decade. On command, such a robot would be able to move freely within an unstructured environment and perform a wide variety of tasks with minimal reprogramming required.[6] Yet whether progress such as this occurs is dependent on the amount of continuing basic research in all the sciences related to robotics.

Dr. James Albus of the National Bureau of Standards considers that, if we are to provide such a significant impact in this area, the need exists to increase our nation's research in terms of--"at least one, perhaps two, orders of magnitude greater than what has been done to date.[7] He further points out that robotics research must be done on a systems approach. Continuity is critical and, therefore, research centers which are consistently well funded are a must.

Unfortunately, neither US industry nor government agencies appears to be moving in that direction. In fact, today's efforts are mostly fragmented. Total National Science Foundation funding for university research in robotics and related fields is only around $5 million per year. Another $4 million is received from other sources, but too often all these efforts tend toward small projects involving only two to three people.[8] Research efforts by nonprofit laboratories amount to $350 thousand per year, and most of this is funded by industrial affiliates. Research efforts by private industrial laboratories, or among the twenty or so robot manufacturing companies which have research laboratories, amounts to around $15 million per year. Finally, the total for robotic research conducted in government institutions amounts to only $10 million per year.[9]

Efforts toward continuity and planning are not receiving emphasis in the United States. This is especially evident when compared to overseas foreign research projects. Though exact figures are difficult to confirm, the United States is surely running behind in the robotics field where once it was the leader. Japan, for instance, has announced a program to provide some $150 million over seven years to foster the development of advanced robots.[10] Western European countries are estimated to be spending from two to four times as much as the United States in basic robotic research alone.

The Free World is not alone in its quest for robot technology. The Soviet Union has launched an all-out effort to catch up with the West in industrial robots. Most estimates put the Soviet Union from five to ten years behind the

United States, Western Europe, and Japan but that could change quickly. Leonid Brezhnev, at last year's 26th Congress of the Communist Party, directed the efforts of 22 different ministries to build 40,000 robots during the current five-year plan.[11]

Other countries have also put robotics high among their national priorities. Japan, for instance, has made the development of automated factories a high item of national policy. In Europe research is also heavily subsidized by government funds. Both Japan and Europe treat robotic technology as critical to national economic development.

Even if more funds were available, the lack of a national commitment to long-term robotic research puts the United States at a serious disadvantage. In sum, current applications of robotics in the United States are probably best characterized in a report published by the Eikonix Corporation which indicates that applications are "slow, orderly, and uneventful."[12]

Applications: Most robotic systems today are designed for applications in industry. Since potential Army applications are not confined to this area alone, this study will consider robotic uses in the military industrial and nonindustrial environments.

In the industrial area, existing robotic technologies are being applied to Army related manufacturing operations where they have proved cost effective. Many tasks found in Army depots, such as painting, welding, could be or have already been successfully performed by robotic equipment. Further direct applications in the industrial sector could prove of significant benefit by reducing weapons cost inflation, shortening delivery times of critical weapons components or increasing product quality levels.

Robotic devices are especially suited for military related industries because they are multifunctional and can be reprogrammed with relative ease.

Changing production requirements, which might result from a national emergency, could be more easily implemented with robotic equipment than with purely automated machinery. It is even feasible to stockpile general purpose manipulators for use in the event of unexpected requirements.

Among nonindustrial uses, robotic equipment may well prove to be of significant benefit to the US Army in the combat, combat support, and combat service support mission areas. Clearly, robotic equipment shows potential for enhancing the capability of existing weapons systems. The adaptable characteristics of robots make it possible to proliferate many weapons systems which were originally designed for human use only. For example, the functions of a robotic tank-like vehicle could be completely "robotized" but its actions would be controlled from a "parent" vehicle operated by humans.

Robotic equipment has already proved its effectiveness and adaptability in a variety of hostile environments such as underseas, space flights, and in nuclear research. Other roles are envisioned in the battlefield support area; roles which would result in undegraded operations in darkness, battlefield obscurants, or chemically contaminated environments. It is also possible to develop robots which have capabilities not yet possessed by humans; that is, they could be agile, autonomous or semiautonomous vehicles able to withstand great accelerations or other stresses such as the impact of shell fragments.

Finally, perhaps the most significant motivation for using robotics in military context stems from the manpower issue. Escalating manpower costs make intensive use of personnel for production tasks prohibitively expensive. Robotics could contribute to reducing manpower shortages (the result of declining birthrates) by replacing soldiers in some of the more structured tasks or by enabling soldiers to perform more efficiently when augmented by robots.

The 21st Century Battlefield: To envision how robotics might contribute to warfare in the next century, this part of the report proposes applications in each functional area of the Airland Battle 2000 concept.

Battlefield Environment: The authors of Airland Battle 2000 describe a battlefield environment which will be densely populated with sophisticated combat systems whose range, lethality, and employment capabilities surpass anything known today.[13] The airspace over that battlefield also will be saturated with aerial and space surveillance, reconnaissance, and target acquisition systems. Conflicts will be intense and devastating, particularly at any point of decisive battle. The potential for confusion in such an environment will be greatly magnified compared to that in which the Army now trains. Command and control obviously will be complicated to a much greater degree than it has in the past.

Battles in this environment will be waged with systems from all arms and services. No single system will dominate. Finally, the capability of many countries to develop and manufacture nuclear, chemical, and biological weapons will make it imperative that our forces plan from the outset to fight dispersed and to integrate conventional, nuclear, chemical, and electronic weapons.[14] Such a battlefield could occur anywhere in the world. Though Airland Battle 2000 references Soviet and Warsaw Pact forces frequently, conflicts could also involve their surrogates who would be equipped and trained in a similar manner by Soviet forces.

Airland Battle 2000 also considers major worldwide trends that will force change and present alternatives from which the US Army must choose if it is to properly prepare for conflict in the 21st century. This report comments on some conclusions, drawn from those trends, which have a direct relationship to potential robotic uses.

Among those conclusions is that by the year 2000 half the population of the United States is projected to be over the age of forty. Declining birthrates, coupled with a movement from an industrial-based society to one characterized by high-technology exploration and information systems, will result in the US Army being high-technology intensive.[15]

Another conclusion describes the world's traditional industrial giants as directing their attention to the high-technology sector. This forecasts new and improved ways of doing more with less. Robotics, for instance, will help offset the manpower decline mentioned above. Computer assisted decision-making will help transform this once tedious task into one which can be accomplished more quickly and accurately. The impact which technology will have on the battlefield will be characterized by greater mobility, firepower, intensive maneuver forces capable of independent operations, and by broadscale battle plans which will be complex but readily synchronized by using artificial intelligence.[16] Technology will also enable the structuring of small, yet highly effective, combat units which will be capable of waging battle through agility, deception, maneuver, and all other tools of combat. Their actions will confront the enemy with a succession of dangerous and unexpected situations more rapidly than he can react to them.[17]

Robotic Applications: This report proposes robotic applications in conflict in terms of battlefield functional areas as does Airland Battle 2000.

o Command and control. Though only partially robotic by definition, command posts (CP) will enhance command and control by using artificial intelligence techniques. Microcomputers will be compatible for processing information as well as assisting in situation assessments, decisionmaking and planning strategies. These systems will also provide automatic reproduction of operational situation displays as well as critical logistical and personnel data. Robotic-artificial intelligence supported voice discriminators and scramblers will be inherent to those CPs. Robotized airspace management techniques will help control friendly air traffic quickly while, concurrently, identifying friend from foe and tasking air defense elements to attack those aerial platforms identified as hostile.

Command and control on this battlefield will also be enhanced by robotic controlled, deceptively oriented, command posts which will be capable of making frequent preprogrammed moves and transmitting from what appears or sounds like an operational command post. These CPs could contribute to the enemy's confusion and will likely prolong, if not stifle, enemy decisionmaking processes, thus allowing US forces to retain the initiative.

o Close combat. Robotic "pointmen" could be used in a dismounted or mounted close combat role. These devices, which will probably not look anything like a man, could provide essential advanced warning to patrols or advance parties. They will be lightweight, portable, with sufficient sensors and artificial intelligence capabilities to enable them to detect and analyze environmental changes which are inherent to enemy boobytraps or ambushes. They could be used to determine possible paths or routes, thereby greatly reducing the risk of soldiers.

Close combat forces could also be augmented with a variety of robotic platforms. One such platform might be capable of detecting laser irradiation. Mobile, semiautonomous laser designators could be developed that can search for, identify, and track targets. Combined with laser seeking missile launchers, these platforms would become self-sufficient, self-contained, semi-autonomous combat systems.

Target acquisition for the close combat force could also be enhanced by robots. These robots, capable of detecting and discriminating targets, could be made even more effective by programming them with a criteria logic which would enable them to select the highest priority target from among several on the battlefield.

Target engagement by semiautonomous, robotic firing platforms is also potentially within the state of the art. Though some problems currently exist relating to sensor performance, sensor data processing, target prioritization, aiming, tracking, and firepower allocation, research in improved sensors and applied artificial intelligence would likely overcome most of them. Substituting a fire-and-forget missile also could eliminate the need for precise aiming and tracking.

Robotic systems could be used extensively by close combat forces in a number of other high risk missions. They could operate uninhibited in nuclear, biological or chemical (NBC) environments for instance. Robotic NBC decontamination platforms could perform standard decontamination procedures as well as disassemble material when necessary to apply decontaminants in hard to reach locations. When associated with bath and laundry units, the entire man-material decontamination effort could be robotized. In addition to decontamination, robotic platforms could also be programmed to use NBC monitoring equipment. They could be dispatched to designated areas, discern environmental hazards present, and report to command centers specifics such as locations, types of contaminants, and quantities present.

Robotized automatic loaders for the current family of tank, artillery, mechanized infantry and helicopter weapons systems, as well as for future close combat weapons systems, could also be developed. These loaders could use visual and tactile sensors to select ammunition, set fuses if required, and transfer rounds from stowage areas to the guns.

One-man or unmanned weapon stations--perhaps helicopters, tanks, or artillery--could also be robotized. In the one-man system all positions other than that of gunner/commander could be robotic and controlled from a central location. A robotic weapon system might be employed as part of a platoon or section with the leader manning a "parent" vehicle. His ability to employ the unmanned systems in overwatch or as part of a coordinated offense or defense would be limited only by the video display element, microcomputer capacity or the degree of training he possessed.

o Fire support. Robotic forward observers which could identify targets, call for, and adjust fires, would contribute to this functional area. These platforms could be augmented by artificial intelligence systems programmed with target data and artillery procedures. A robotic forward observer programmed in this way could transmit calls for fire in a variety of languages or by data alone. Robotic forward observers could be especially valuable in directing fires against enemy targets in the extended battle area or the extended reconnaissance and surveillance area.

o Air defenses. Robotic in nature, acquisition platforms could be dispatched to key positions along likely enemy air avenues of approach or positioned much like sentry robots are in close proximity to critical facilities. Using a friend or foe target identification system and being linked electronically to air defense weapons systems, these acquisition robots could contribute substantially to accomplishing the air defense mission.

Used in countersuppression roles, robotic air defense platforms could either destroy or neutralize enemy suppression, reconnaissance and target acquisition systems by either engaging them or merely deceiving them and then quickly displacing to preprogrammed alternate positions. They could enhance their deception mission by automatically discharging obscurants or initiating jamming once their knowledge bank recognized a distinctive hostile communication transmission.

As with all other robotic platforms, these, too, would require less sustaining support than manned systems, and, additionally, would be capable of operating for several days or weeks because of reduced requirements for fossil fuels.[18]

o Intelligence and electronic warfare. Semiautonomous robotic platforms, similar to those described above, could contribute in this functional area by firing electronic weapons from command designated positions against targets whose hostile descriptions were stored in the robot's knowledge bank. Disruption missions could be enhanced by using robotic platforms to jam enemy systems or launch terminal homing munitions targeted against specific enemy command and control facilities or other critical nodes. Robotic jamming and launching devices could be programmed to relocate automatically to a more compatible electronic environment when threatened.

Robotic deception devices, either mobile or stationary, could stimulate the activities of specific units or an entire combat engagement. This simulation might involve computer generated uses of electronic emissions, simulated communications, noise, or other indicators which would mislead the enemy.

Robotic platforms, equipped with microcomputers and specialized sensors, could perform battlefield reconnaissance also. Air and ground platforms could navigate, collect information, correlate it, and transmit results to a designated command and control facility. Surveillance data would then enter an all-source intelligence center and be available for intelligence specialists to use as they analyzed the enemy's activities. Artificial intelligence supported image processing could assist intelligence specialists in detecting the enemy's efforts at deception and could also provide real-time target coordinates.

Another part of this family of robotic platforms could emplace remote sensors to increase targeting capabilities, especially under adverse weather conditions. These same platforms could have microcomputers which would record sensor signals and provide immediate target recognition analysis.

o Combat support, engineer, and mine warfare. Robotic applications in mine warfare have already begun. Experiments at Fort Knox, Kentucky, are underway in early versions of what eventually could be a semiautonomous robotic platform with artificial intelligence designed to detect and mark, or breach enemy minefields.[19]

Still other countermobility robotic platforms could roam the battlefield and when an environment met their preprogrammed hostility threshold they could emplace "smart" mines. These mines would be capable of recognizing and harrassing enemy movements. The "parent" robotic mine dispensing platform could use its innate artificial intelligence to relocate to other positions as required to engage other enemy targets or to protect itself. Self-destruction or command detonation of the "smart" mine could be inherent to the system.

Robotic platforms could perform a number of other countermobility tasks also. They could dig ditches, make craters, build abatis or other obstacles, and install barbed wire once patterns, quantities, and locations were programmed in their knowledge banks. They would likely have multipurpose or multiple manipulators (the end effectors which do the digging, grasping, etc.) and an artificial intelligence capability which would enable them to determine the location and extent of obstacles required based on input concerning the enemy. These same platforms could be used to remove obstacles since their knowledge banks would serve as an obstacle plan and recording system. Robots such as these would reduce the requirement for soldiers to perform routine countermobility tasks, leaving them to plan, coordinate, and emplace more complex or intricate obstacle fields.

o Combat service support. Perhaps this is the functional area with the greatest near- to mid-term potential for robotic applications.

Responsibilities in this area extend from the production base in the United States, through offshore sites and finally into the area of combat operations. Since potential applications for robots in the industrial, military equipment production, and manufacturing sectors were discussed earlier, this section is directed primarily at offshore and operational area combat service support applications.

First, however, there are a number of applications which arise during the soldier's initial entry training period that also relate to this functional area. Robotic physical examination centers are definitely within the state of the art by the next century. Even now, for instance, it is common for people to frequently use coin operated blood pressure machines. A robotized physical examination center would merely be an extension of this trend. The requirement for doctors, while not eliminated entirely, would certainly be reduced.

In much the same way, entire administrative processing centers could be robotized. Obviously, some human presence should be retained to assure inductees feel the impact and emotion of joining a cohesive organization. However, there is no reason why voice activated, artificial intelligence devices could not assume many administrative functions such as aptitude testing, personnel or pay processing, and uniform or equipment issue.

There are a number of potential robotic applications in the training base environment also. Current efforts toward computer assisted instruction and arcade-type training devices should be viewed as first generation approaches. There is, for instance, no reason at all why weapon ranges of the future would have to be manned by humans. Entire range operations are destined to be robotized--from robot targets, to scoring, and, finally, to voice-supported critiques. Robotic training devices designed to support unit training efforts are also a possibility worthy of investigation.

At various offshore sites and in the area of operations, wherever sustaining base support maximizes use of host nation support, the United States should encourage and support robotic applications. Depot and port facility operations are prime examples. Where combined operations are supported through use of multinational commodity centers, efforts should be made at robotizing these activities. All of these applications could conserve manpower for tasks which are more sensitive and complex.

Logistical support for close combat forces will be conducted by highly mobile logistical elements. Since onsite support in the immediate battle area will be limited to combat essentials--requirements which are simple and rudimentary--robotic resupply platforms could be of substantial use. In instances where resupply was critical to the viability of a unit, robotic platforms, perhaps of an air cushion nature which were preprogrammed to rendezvous at designated locations, could deliver the goods. Alternatively, logistics operations centers might control the movement of these platforms through a vidio-display screen which tracked their location and communicated directions either by electronic impulse or by tracing the robot's intended route on the display screen.

Normally, major logistical support will occur at reconstitution points. It is here that resupply of all man-machine systems will take place. It is here, too, that robotic vehicle diagnostic and repair systems could conduct limited rebuild and major component replacement activities. A semiautonomous or autonomous robot could be programmed to assist maintenance personnel in repairs or, in some cases, perform the repairs itself. When linked with an artificial intelligence system, the robot could diagnose problems, identify corrective action, and, when properly preprogrammed, conduct necessary repairs. Reconstitution points could also contain completely robotized rest and recuperation centers. These centers might be self-contained vans equipped with movies, video-cassette home letter machines, miniphysical therapy accommodations or other such items.

Food preparation and distribution processes at the reconstitution point, not unlike those found elsewhere in this environment, could also be robotized. Prepackaged, high nutritional meal packets could be selected by soldiers to satisfy individual appetites. Microwave preparation and trash compactors would be integral to these centers.

Reissue of personal clothing could be made from mobile, robotic distribution containers. By positioning a number of these resupply modules at the reconstitution point, soldiers could be able to draw replacement items of equipment by activating pushbuttons keyed to the item they needed. When the dispersing module was below minimum stockage levels, it could automatically return to a parent depot for further replenishment.

Ammunition and fuel resupply could also be totally automated. Refueling, whether with petroleum products for the older family of vehicles or with nonfossile fuels for the newer family, could be done by robotic systems. Ammunition resupply and other heavy, cumbersome efforts could be accomplished by integrating the use of automated material handling equipment and artificial intelligence sensory systems. Prototypes of these robots are now being built.[20] Major ammunition supply depots could be robotized also to take advantage of automated inventory procedures, safety factors, and "smart" material handling machines. For that matter, entire ammunition production plants could be robotized. Such an effort could enhance sustantially that part of the production base.

Evacuation of dead and wounded could also be accomplished by robotic vehicles similar to those which provide urgent logistical support to close combat forces. When evacuating dead, these vehicles, programmed to designated close combat units, could be loaded and by merely activating a switch dispatched to the nearest mortuary. When medical evacuation of wounded was required, aerial, all-weather capable robotic platforms could also be used. Upon receipt of an evacuation request they would be programmed and dispatched to the unit in conflict. Having been vectored in and loaded with wounded, their return could be reprogrammed by merely closing a latch.

At medical treatment centers robotized triage machines could be used. These life-sustaining diagnostic devices, patterned after today's life support systems, would quickly monitor the vital signs, identify the most critical injuries, and thereby assist medical personnel in establishing priorities for treatment.

Traffic control in the service support area could also be enhanced by robotic devices positioned at key road junctions. Early versions of these devices are already in use. With added artificial intelligence, they could be programmed to sort out complex congestion related problems by means of sensory perception and memory algorithms.

Part of the rear area security mission could also be accomplished by robotic devices. Security of critical installations could be provided by advanced generation sentry robots. Able to recognize friend from foe, these robots could substantially reduce the requirement for guards at sensitive facilities, depots, or headquarters.

Other Military Applications of Robotics. There are a number of other applications, not necessarily peculiar to the US Army, which should be considered. The military's rapid-deployment tasks could be lessened by robotized, pilotless troop and equipment transporters. These vehicles might vary in size and duration of flight depending on their mission, but in each case, preprogrammed flight patterns and ground effect or obstacle avoidance sensors would be key to their employment. They might vary from something akin to a pilotless helicopter or air cushion vehicle to a major transport vehicle. Considering that today's space flights, even C5A or other commercial flights, can be, and in many instances are, entirely controlled by microcomputers, there is little technological reason why inter- and intra-theater deployment vehicles could not be robotized.

Robots have already made their entree in the space exploration effort. Their potential applications in this environment are virtually limitless. Robotic space platforms, which provide acquisition or indirect fire support to earth battlefields, are a very real possibility.

Robotic, semiautonomous or autonomous submarines or surface vessels could enhance the country's maritime mission much the same way land based robotic platforms could support land forces. Efforts are already underway to develop an underwater robot to search out mineral deposits on the ocean floor.[21] That same technology could be applied to searching for underwater mines or even submarines themselves.

One final area in which robotic-artificial intelligence could have potential application lies in the strategic warning, trans-nuclear and post-nuclear strike periods. During these periods, when humans will be under considerable emotional stress, assistance from a robotic device which had been preprogrammed, for example, to keep track of the constitutional successors might be invaluable. When integrated into a survivable command and control system, robotic-artificial intelligence devices could assist greatly in determining quickly what the post-strike situation was, either nationwide or in specific geographic areas.

Recommendations. If research and development endeavors were pursued aggressively in the areas mentioned, significant advantages could be realized in the battlefields of the next century. On the other hand, if many of the robotic applications identified in this report are not pursued, the military, and the Army in particular, could miss out on the technological opportunity of the century. To take full advantage of the opportunity, however, an effort on the scale of the Manhatten Project would likely be required. Considering the nation's current economic condition and projections for slow improvement, a somewhat scaled-down emphasis might be more realistic. That emphasis should follow two courses:

o Headquarters, Training and Doctrine Command, whose task it is to levy requirements on material developers based on concept compatible applications, should review the robotic-artificial intelligence applications suggested in this report with consideration given to validating them and establishing their priority. This should be done as quickly as possible and then requirements must be placed on research and development laboratories, as well as others in the community, to develop prototypes which could be fielded by the 21st century.

o Department of Defense or Department of Army should fund and task research and development agencies which are independent of the Materiel Development and Readiness Command (DARCOM) community to pursue the two or three applications which TRADOC concurs would have the highest payoff in Airland Battle 2000. Rapid results from such an effort could be realized since they would be relatively unencumbered by normal research and development bureaucratic procedures.

ENDNOTES

1. "Robots: The New 'Steel Collar' Workers," Personnel Journal, September 1981, p. 691.

2. US Training and Doctrine Command, Airland Battle 2000, 4 September 1981, p. 1.

3. Lee Edson, "Slaves of Industry," Across The Board, July/August 1981, p. 5. Plants using these minicarts include General Dynamics in Fort Worth, Texas; Klopman Mills in North Carolina; and General Motors in Lansing, Michigan.

4. Earl C. Joseph, "Future Smart Machines and Computers," Futurics, 1981, p. 266.

5. Ibid., p. 267.

6. US Congress, Office of Technology Assessment, Exploratory Workshop on the Social Impacts of Robotics, p. 7.

7. Ibid., p. 69.

8. Ibid., p. 71.

9. Ibid., p. 72.

10. Henry Scott Stokes, "Japan's Love Affair With the Robot," The New York Times Magazine, p. 75.

11. "Russian Robots Catch Up," Business Week, 17 August 1981, p. 120.

12. Stokes, p. 80.

13. There is a school of thought which considers that the 21st Century battlefield will have changed so drastically due to population and urban/industrial expansion that the term "battlefield" will be anachronistic and its dimensions so uncertain that detailed descriptions are not possible. See Charles W. Taylor, A Concept of a Future Force, 2 November 1981, p. 2.

14. Airland Battle 2000, p. 2.

15. Ibid., p. 14.

16. Ibid., p. 16.

17. Ibid., p. 17.

18. Ibid., p. E-6.

19. Jim Tice, "Robot Vehicle Breaches Minefield in Test," Army Times, 19 October 1981, p. 20.

20. Tice, "Robot Device to be Tested for Howitzer Loading," Army Times, 2 November 1981, p. 12.

21. US Congress, Office of Technology Assessment, Exploratory Workshop on the Social Impacts of Robotics, p. 75.

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This report identifies potential military applications of robotic-artificial intelligence technology and considers near-, mid-, and far-term technology projections. Criteria for applications of robots include their potential cost effectiveness; the speed, accuracy and uniform quality of effort which robots can achieve; their ability to perform in hazardous environments; their role as soldier replacements or multipliers; and their ability to save lives on high risk missions.

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